COSEWIC
Assessment and Status Report

on the

Nahanni Aster
Symphyotrichum nahanniense

in Canada

SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Nahanni Aster — Photo by Allan Harris (with permission).

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Nahanni Aster

Scientific name
Symphyotrichum nahanniense

Status
Special Concern

Reason for designation
The global population of this species is restricted to hot springs in Nahanni National Park Reserve. A very small range and population size make this endemic species susceptible to losses through natural alterations due to geothermal processes or to landslide events that may become more frequent as climate warms and permafrost melts.

Occurrence
Northwest Territories

Status history
Designated Special Concern in May 2014.

COSEWIC
Executive Summary

Nahanni Aster
Symphyotrichum nahanniense

Wildlife Species Description and Significance

Nahanni Aster is a perennial wildflower up to 35 cm tall with white to pale pink flower heads. It typically grows in clumps of about two to ten stems from short, woody rhizomes (horizontal underground stems). The stems are branched to form an open panicle typically with one to three flower heads, but some plants have 15 or more. The number of flower heads appears to vary between sites and may be determined by growing conditions. The stems are green to reddish, often with fine woolly hairs, especially towards the base. Each flower head consists of a yellow disc, surrounded by 15 to 41 white to pale pink rays. Nahanni Aster is endemic to Canada and found only in Nahanni National Park Reserve. It may have evolved here when this part of the Mackenzie Mountains remained unglaciated while the surrounding region was still covered by ice until about 11,000 years ago.

Distribution

Nahanni Aster is confined to six known sites in the southern Mackenzie Mountains of the Northwest Territories, within about 110 km of each other. The hot springs are mostly arranged along two major faults. The southeast – northwest trending Broken Skull Fault follows the valley of the South Nahanni River and lies beneath the Rabbitkettle Hotsprings. Another fault extends down the valley of the Flat River.

Habitat

Nahanni Aster is found at hot and warm spring habitats with tufa (calcium carbonate deposits). Nahanni Aster grows around the edge of the springs and along the streams and seepage discharging from the spring. It is rooted in moss, but also occurs in broken old tufa and dense turf with various rushes and sedges and is typically unshaded by trees or shrubs.

Biology

Very little is known of the biology of Nahanni Aster. It is a perennial species forming clumps of flowering stems with multiple shoots. It reproduces both by seed and asexually using short rhizomes. Flowering occurs in August to September. Nahanni Aster occurs exclusively at a limited number of springs in a small geographic area, suggesting that it tolerates a narrow range of habitat conditions. Dispersal presumably occurs by wind-borne seeds, as is the case with other aster species. Dispersal between springs is probably limited by the scarcity of suitable habitat.

Population Sizes and Trends

Nahanni Aster population fluctuations and trends are unknown due to the lack of consistent and comprehensive surveys. Comparison of the 2012 data with a 2003 survey shows no apparent change in the distribution of plants or area occupied. Two additional sites have been discovered since 2003. A minimum of over 5600 flowering stems (mature individuals) was counted in 2012. Given the scarcity of springs with tufa, the species is highly unlikely to be much more widespread or abundant than currently known.

Threats and Limiting Factors

Nahanni Aster habitat is protected from industrial development and roads by its isolated habitat and protected status in the Nahanni National Park Reserve. Climate change is the most likely threat to Nahanni Aster habitat. The climate in Nahanni National Park Reserve is warming and rainfall patterns are changing. Changes in groundwater discharge at hot springs due to climate change and seismic activity are potential threats. Its extremely limited range (six occurrences covering less than 10 ha in total) make it vulnerable to random environmental events.

Protection, Status, and Ranks

As all known localities of Nahanni Aster are within the boundaries of Nahanni National Park Reserve, Northwest Territories, the plant and its habitat are afforded some degree of protection under the *Canada National Parks Act* and Regulations. The species receives no specific protection under federal or territorial laws. It is ranked globally, nationally, and territorially as Critically Imperilled (G1, N1, and S1) by NatureServe and as "may be at risk" by the General Status program, both in Canada and the Northwest Territories.

TECHNICAL SUMMARY

Symphyotrichum nahanniense
Nahanni Aster — Aster de la Nahanni
Range of occurrence in Canada: Northwest Territories

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used) *Apparently a long-lived perennial species, but reproductive and demographic data are lacking.*	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Comprehensive population trend data are unavailable, but more flowering stems were recorded in 2012 than in previous surveys at the four sites where comparable data are available (Table 1).*	No
Estimated percent of continuing decline in total number of mature individuals within 2 generations	Unknown
Suspected percent increase in total number of mature individuals over the last [10 years, or 3 generations]. *Comprehensive population trend data are unavailable, but more flowering stems were recorded in 2012 than in previous surveys at the four sites where comparable data are available (Table 1).*	Unknown
Suspected percent increase in total number of mature individuals over the next 10 years.	Unknown
Suspected] percent increase in total number of mature individuals over any 10 year period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	N/A
Are there extreme fluctuations in number of mature individuals? *The life history of this species, along with observations of the extent of local populations argues against the existence of extreme fluctuations.*	No

Extent and Occupancy Information

Estimated extent of occurrence	2,834 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	24 km²
Is the population severely fragmented? *Although the habitat consists of small patches of hot springs distributed over a large area, the areas appear to be large enough to maintain viable populations.*	No
Number of locations* *An estimated maximum of five additional localities may be found.*	6

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term

Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population – (see Table 1)	**N Mature Individuals (i.e. flowering stems)**
86-030	>1035
Old Pots	>1000
Rabbitkettle	203
Sibbeston	>900
Thirteen Steps	>1000
Wildmint	>1500
Total	>5638

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	n/a

Threats (actual or imminent, to populations or habitats)

Changes in groundwater discharge at hot springs due to climate change or seismic activity is a potential threat.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *Nahanni Aster is endemic to the Northwest Territories.*	None
Is immigration known or possible?	Not possible
Would immigrants be adapted to survive in Canada?	n/a
Is there sufficient habitat for immigrants in Canada?	n/a
Is rescue from outside populations likely?	No

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Data-Sensitive Species

Is this a data-sensitive species?	No

Status History

COSEWIC: Designated Special Concern in May 2014.

Status and Reasons for Designation:

Status:	**Alpha-numeric code:**
Special Concern	Not Applicable
Reasons for designation: The global population of this species is restricted to hot springs in Nahanni National Park Reserve. A very small range and population size make this endemic species susceptible to losses through natural alteration of geothermal processes or to landslide events that may become more frequent as climate warms and permafrost melts.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met. No declines have been demonstrated.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not met. Though below the threshold for Endangered with an EO < 5,000 km² and an IAO < 500 km², and there are <10 locations, there are no demonstrated declines, the population is not considered to be severely fragmented, and the population is not known to undergo extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not met. Though the population is likely <10,000 mature individuals, no decline has been observed or suspected.
Criterion D (Very Small or Restricted Population): Not met. Comes close to meeting Threatened D1 because the actual number of mature individuals may be below the threshold of 1,000. Comes close to meeting Threatened D2 because the Canadian population occupies a very restricted IAO (24 km²). However, it is uncertain if this species is prone to stochastic events capable of causing the species to become Endangered or Extinct in a very short period of time.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Nahanni Aster

Symphyotrichum nahanniense

in Canada

2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Symphyotrichum nahanniense* (Cody) Semple

Common name: Nahanni Aster (Aster de la Nahanni)

Synonyms: *Aster nahanniensis* Cody

Family name: Asteraceae, (Aster Family)

Major plant group: Angiosperm (eudicot flowering plant)

Nahanni Aster was first described by Scotter and Cody (1974) as *Aster nahanniensis*, but is treated as *Symphyotrichum nahanniense* by the Flora of North America (Brouillet *et al.* 2006). No varieties or subspecies are recognized (Brouillet *et al.* 2006). The taxonomic status of *Symphyotrichum nahanniense* has been subject to debate (Owen *et al.* 2006). Kartesz (1999) and Nesom (1994) included *Symphyotrichum nahanniense* with *S. falcatum* var. *commutatum*, but Brouillet *et al.* (2006) and Kartesz (2011) treat it as *S. nahanniense*. Owen *et al.* (2006) distinguished *S. nahanniense* from other members of section *Dumosi* (i.e. Rush Aster, *S. boreale* and Welsh's Aster, *S. welshii*) on the basis of morphological differences. Nahanni Aster is diploid (2n = 16) (Owen *et al.* 2006).

Morphological Description

Nahanni Aster is a perennial wildflower up to 35 cm tall with white to pale pink flower heads. It typically grows in clumps of about two to ten stems from short, woody rhizomes (horizontal underground stems). The stems are branched to form an open panicle typically with one to three flower heads, but some plants have 15 or more (Figure 1). The number of flower heads appears to vary between sites and may be determined by growing conditions (Owen *et al.* 2006). The stems are green to reddish, often with fine woolly hairs, especially towards the base. The leaves are linear to lanceolate, entire, and sessile or weakly clasping the stem. Each flower head consists of a yellow disc, surrounded by 15 to 41 white to pale pink rays (Porsild and Cody 1980; Brouillet *et al.* 2006). The achenes (seeds) are tan coloured and 2 to 3 mm long with short, stiff bristles (Brouillet *et al.* 2006). The pappus is white.

Figure 1. Nahanni Aster at Sibbeston Hotspring (Photo by Allan Harris).

Nahanni Aster is perhaps most likely to be confused with Rush Aster (Owen *et al.* 2006), which also occurs in the Nahanni area (Cody *et al.* 1979) or Welsh's Aster, which is found from Arizona to Wyoming. Both species are considered to be part of the *Symphyotrichum boreale* complex within the *Symphyotrichum* section *Dumosi* (Owen *et al.* 2006). The two species are best separated on a combination of traits, such as lower stem pubescence, leaf length, and ray strap length. Compared to these other two species, Nahanni Aster has shorter, narrower middle (distal) leaves (12-72 mm long X 1.6-6.8 mm wide vs. 27-136 mm long X 1.2-11.0 mm wide), shorter stems, and fewer flower heads (Owen *et al.* 2006). Interpopulation analysis of the Nahanni Asters revealed that they differ morphologically depending on their spring site; however, samples sizes were quite small (Owen *et al.* 2006).

Population Spatial Structure and Variability

The known global range of Nahanni Aster is isolated to six hot and warm springs (hereafter referred to as hot springs) in Nahanni National Park Reserve within about 110 km of each other (Figure 2). The species presumably evolved here (Owen *et al.* 2006) and is apparently restricted to tufa deposits at hot springs (see **Habitat Requirements**). The small and highly dispersed nature of suitable springs outside the immediate Nahanni area (Figure 3) may limit the dispersal of this species into surrounding areas.

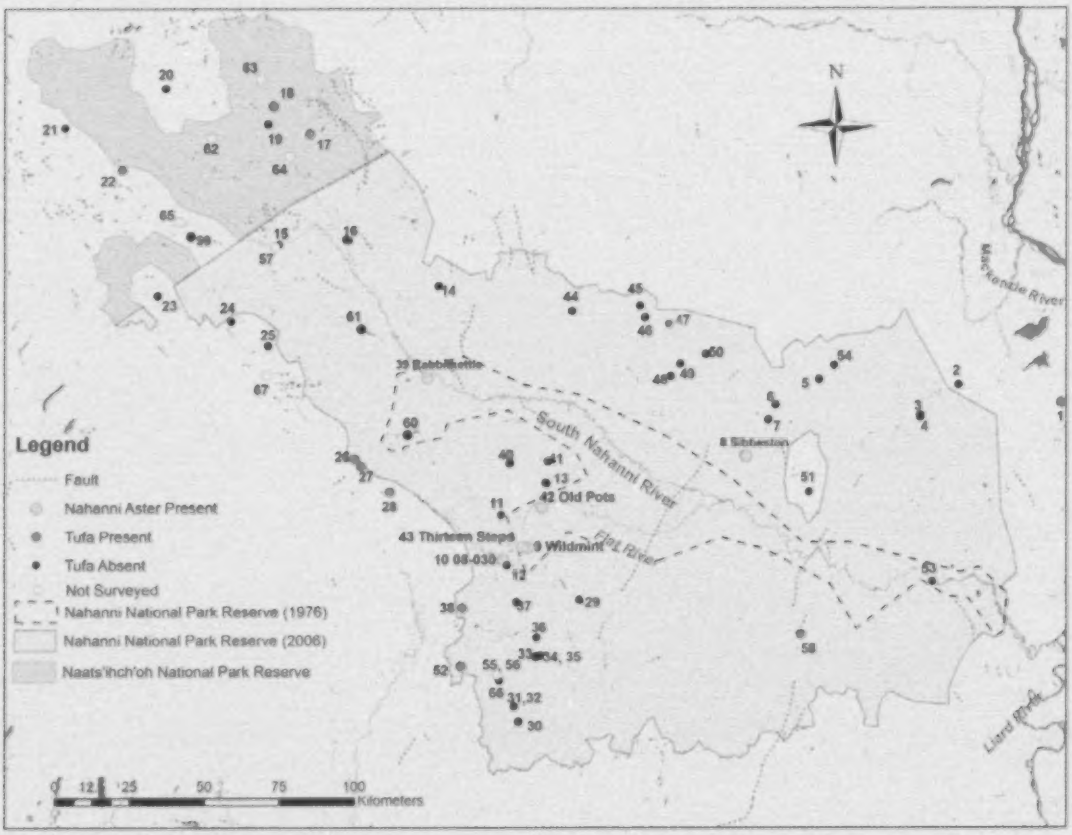

Figure 2. Nahanni Aster populations (green dots) in Nahanni National Park Reserve, and spring locations with tufa (red dots) and without tufa (black dots). Tufa is also present where Nahanni Aster is present. Refer to Appendix 1 for details.

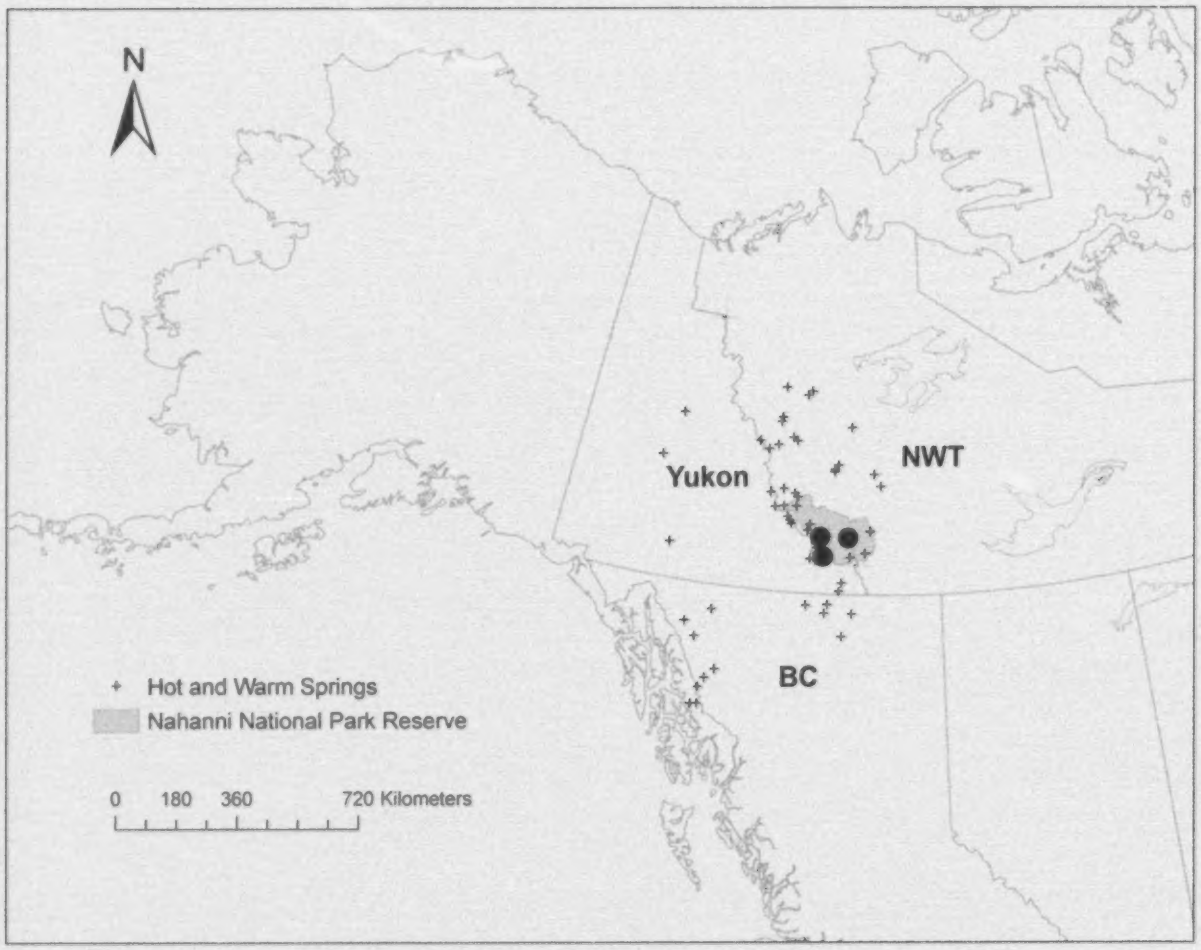

Figure 3. Global range of Nahanni Aster. Dots represent the approximate sites of Nahanni Aster populations. Small crosses representing hot and warm spring locations in northern BC, Yukon, and NWT are from Woodsworth (1999) and Government of the Northwest Territories (2012).

Several hot springs in the intervening areas between existing populations of Nahanni Aster are potential habitat that could facilitate dispersal within the Nahanni area, although dispersal between sites has not been demonstrated. Morphological variation (stem height, leaf length, etc.) between Nahanni Asters at Old Pots, Rabbitkettle, Thirteen Steps, and Wildmint hotsprings may suggest that these populations are at least somewhat isolated from each other, but sample sizes were small and the differences may be related to growing conditions rather than genetic variability (Owen *et al.* 2006).

Designatable Units

The Canadian (and global) population comprises a single designatable unit within the Northern Mountains Ecological Area (on the western edge of the Boreal Ecological Area) (COSEWIC 2012). All occurrences are in similar habitat types within a maximum distance of about 110 km of each other. Although there are minor morphological differences between Nahanni Asters at different hot springs (Owen *et al.* 2006), plant morphology could be influenced by nutrients, temperatures, or other environmental factors rather than genetic distinctiveness.

Special Significance

Nahanni Aster is one of very few plant species endemic to Canada and poses interesting questions about the postglacial history and origin of the flora of the Nahanni area. The species may have evolved from its parent species when this part of the Mackenzie Mountains was deglaciated about 11,000 years ago while the surrounding region was still covered by ice (Owen *et al.* 2006). Alternatively, Nahanni Aster may have persisted through the last glacial maximum in an unglaciated refugium (Dyke 2005; Loehr *et al.* 2006; Bennett pers. comm. 2012) (Figure 4). The ecological role of Nahanni Aster is unknown. It has no known human use. The Nahanni Aster is often referenced in Parks Canada publications and visitor information about Nahanni National Park Reserve, but is otherwise not well known by the general public.

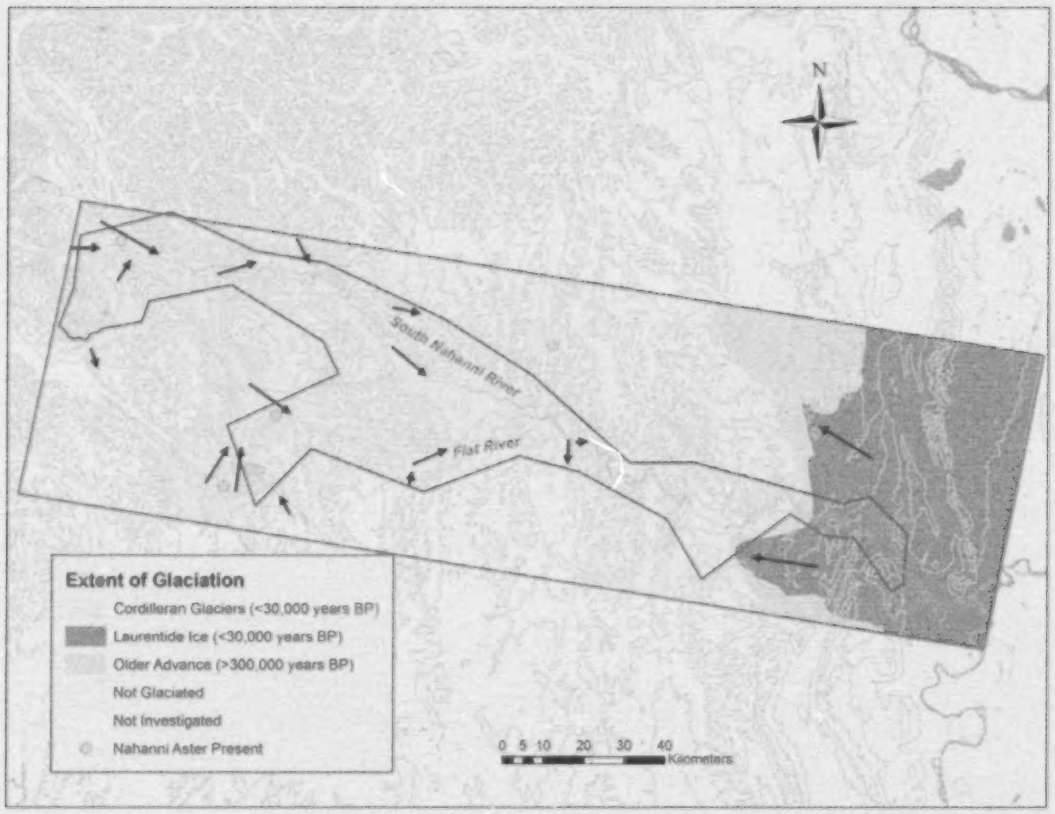

Figure 4. Maximum extent of glaciation in part of Nahanni National Park Reserve and Nahanni Aster localities. Arrows represent direction of ice movement. Adapted from Ford (1976); the current size of the Nahanni National Park Reserve now (2013) is much larger, as illustrated in Figure 2.

DISTRIBUTION

Global and Canadian Range

Nahanni Aster is endemic to Canada, and confined to six known sites in Nahanni National Park Reserve, in the southern Mackenzie Mountains of the Northwest Territories (Figures 2, 3). There are no known extirpated populations.

Four of the sites (Old Pots, Wildmint, Thirteen Steps, and 86-030) are clustered within about 22 km of each other along the Flat River in the south-central part of the park. Rabbitkettle Hotspring is just south of the South Nahanni River about 50 km to the northwest, and Sibbeston Hotspring is about 80 km east; 17 km northeast of the junction of the Flat and South Nahanni rivers.

In Nahanni, many (but not all) hot springs are arranged along two major faults. The southeast – northwest trending Broken Skull Fault follows the valley of the South Nahanni River and lies beneath the Rabbitkettle Hotsprings (Figure 2). Another fault is believed to extend down the valley of the Flat River (Gulley 1993).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EO) of Nahanni Aster in Canada is 2,834 km^2 as measured by a minimum convex polygon.

The index of area of occupancy (IAO) is 24 km^2 (i.e. occurs in six 2 km X 2 km grid cells). The actual area occupied by Nahanni Aster as estimated in the field is about 9 ha (Table 1).

Table 1. Nahanni Aster population details from the 2003 and 2012 surveys. Water chemistry and temperature data from summary by field measurements (Lepitzki and Lepitzki 2004; Caron *et al.*, 2007).

Name	Est. Flowering Stems 2012	Est. Flowering Stems 2003*	Approx. Area Occupied (ha) 2012	Notes 2012	Elevation (m)	pH	Cond (uS/cm)	Max. Temp (°C)
Thirteen Steps	>1000	>100	1	Over 1000 stems distributed over about 100 m X 100 m. Some rooted in dense mat of *Juncus* sp. Others rooted in fairly dry broken up tufa (these plants only 5 to 6 cm tall).	667	7.19	475	14
Rabbitkettle	203	>50	0.04	Nahanni Asters are at the second smaller tufa mound. No plants at the big mound. Mostly 1 flower head / stem. These plants (unlike other sites) are past peak flowering.	642	6.40-7.61	1030-1135	22
Wildmint	>1500	> 1000	6	Distributed over about 200 m X 300 m. Most plants in the east half of the opening, but sparsely distributed in the west half. Some on old beaver dam. Plants at peak flowering. Many rooted in broken up tufa gravel.	677	7.32-8.00	457-586	29
Old Pots	>1000	> 150	1	Distributed throughout site. Many plants with 3-5 flower heads. Many in relatively dense sedge meadow vegetation.	663	7.60	323	10
Sibbeston	>900	Not surveyed	1	Plants distributed along braided stream on hillside. Tufa deposits poorly developed. Most plants in mossy cushions within 2 m of stream.	795	7.65	340	18
86-030	>1035	Not surveyed	0.2	Asters rooted in moss at edge of stream and throughout sedge meadow. Most common at the lower end of the hot spring. Plants scattered on mossy gravel hummocks.	706	6.68	776	19

*Semple pers. comm. 2011

Search Effort

General botanical surveys were conducted in the Nahanni area between 1961 and 1976 by Scotter, Cody, Talbot, and others (e.g. Scotter and Cody 1974; Cody *et al.* 1979). Although these surveys did not specifically target Nahanni Aster, surveys did include potential habitat at hot springs. Botanical surveys in the southern Mackenzie Mountains and elsewhere in the Northwest Territories between 1922 and 1980, are summarized in Addison (1974) and Porsild and Cody (1980).

The Nahanni Aster was first collected during these early investigations along the South Nahanni and Flat rivers, and described in 1974 from specimens taken at two sites near the Flat River: Old Pots Hotsprings and Wildmint Hotsprings (Scotter and Cody 1974). The plant was also identified in the mid-1970s at Rabbitkettle Hotsprings, near the South Nahanni River. Staff at Nahanni National Park Reserve have undertaken near-annual visits to Wildmint Hotsprings and occasional visits to the other two known sites since the 1980s (Tate 2003; Owen *et al.* 2006). Botanical surveys at additional springs, including Hole in the Wall and Meilleur (e.g. Line 2001) discovered no Nahanni Asters.

The three springs above remained the only known localities for nearly 30 years, until Dr. J.C. Semple (University of Waterloo), with the cooperation of Parks Canada staff including D. Tate, conducted the first detailed Nahanni Aster survey over the course of four days in August 2003 (Tate 2003; Semple pers. comm. 2011). During this work, an additional site was found near the Wildmint site, named Thirteen Steps Spring. Five other hot spring sites (Kraus, Lened, Meilleur, Moore, and an unnamed spring near McLeod Creek) were also searched for asters by Semple, but none were found.

A fifth spring near the Flat River was visited in August 2004 by Parks Canada staff on unrelated work (Borcoman pers. comm. 2004). A plant specimen collected there was later identified as Nahanni Aster (Semple pers. comm. 2006). The locality was not geo-referenced at the time, but the spring was confirmed during 2012 fieldwork (Harris and Foster 2012) for this report as a hot spring near Mineral Lake (known as 86-030), less than 10 km from the Thirteen Steps site, and asters were documented. The sixth site was discovered by the report writers in 2012 in the Vera Creek basin (Sibbeston Hotspring); it is the farthest east of the sites, and the only one north of the South Nahanni River.

In preparation for this report, a database of known springs in the South Nahanni River watershed was used to map and plan field sampling. The database was derived from information compiled in Wright *et al.* (2007; Figure 2), and contained 67 springs, extending from near the Yukon border to the eastern edge of the Ram Plateau (129.5° W - 123.8° W), and from near the South Nahanni River headwaters south to the upper Caribou River (62.8° N - 60.9° N). Many of the spring names in this database are unofficial names, and some were simply numbered, including the spring near Mineral Lake identified only as "86-030". Unpublished documents (Catto 1987; Line 2001) and Dr. John Semple were also consulted during fieldwork planning.

Between 14th and 16th August 2012, a total of 49 spring sites (including hot and cold springs) were surveyed for Nahanni Aster by the report writers in support of this status report (Appendix 1; Harris and Foster 2012). These sites included one spring known by Doug Tate but not represented in the database, and the only one east of the Nahanni Range. All five previously known sites for Nahanni Aster were surveyed during this work, including the uncertain locality from 2004 (Hotspring 86-030). An additional six springs were surveyed by Bruce Bennett and others in August 2012 in conjunction with ecotype mapping fieldwork being undertaken by Parks Canada (Bennett pers. coomm. 2012; Bennett 2013).

Of the 70 known springs, in and adjacent to Nahanni National Park Reserve, 61 were subjected to targeted surveys for Nahanni Aster between 2003 and 2012 (Figure 2 and Appendix 1). An additional 7 hot springs about 100 km north of the park reserve were investigated by Caron *et al.* (2007) for water chemistry and physical parameters (Appendix 1, Appendix 2), but vegetation data were not recorded.

At least 25 other springs occur elsewhere in NWT, Yukon, and northern British Columbia (Figure 3; Woodsworth 1999; Government of the Northwest Territories 2012). Most have received varying degrees of botanical exploration (Porsild 1950; Porsild and Crum 1961; Steere and Scotter 1978; Scotter and Cody 1979; Ceska 1982; Cody *et al.* 2000; Rosie 2005; Bennett *et al.* 2010). Rush Aster has been reported from some hot springs in northeastern British Columbia (Porsild and Crum 1961; Ceska 1982), but neither Rush Aster nor Nahanni Aster has been reported in any of surrounding areas in southeastern Yukon (Cody 1996; Bennett pers. comm. 2013).

HABITAT

Habitat Requirements

Nahanni National Park Reserve is situated in the southern Mackenzie Mountains (Ecosystem Classification Group 2010), and includes mountain ranges, river valleys, and alpine plateaus. This area has a continental climate with long, cold, dry winters and short, mild summers with moderate amounts of precipitation (Parks Canada 1984).

Nahanni Aster occurs at hot spring habitats with tufa deposits. "Thermal" springs are defined as groundwater discharge points where the water is more than 10°C above the mean annual air temperature (Lepitzki and Lepitzki 2004). Hot springs are sometimes distinguished from warm springs based on water temperatures, but for the sake of consistency with common usage this report will use the term hot spring to refer to all thermal springs. Spring water originates from precipitation and runoff, percolates deep into the bedrock (typically 0.2 km to 1 km) where it reaches temperatures between 60 and 69°C but typically cools to about 20°C at the surface (Gulley 1993; Caron *et al.* 2007). In karst bedrock, waters become saturated with dissolved calcium carbonate. At Rabbitkettle Hotspring, water is discharged to the surface at a downhill point, 10 to 25 years after it enters the groundwater (Gulley 1993). Tufa (used in the loose sense to include travertine) is created when calcium carbonate-saturated waters discharge to the ground surface. Degassing of carbon dioxide causes calcium carbonate to precipitate in the form of tufa. It gradually accumulates to form a series of terraces (Gulley 1993). The mounds at Rabbitkettle Hotsprings required 7,000 to 10,000 years to accumulate (Gulley 1993). Many of the springs are associated with faults or plutons (granite spires) (Grasby pers. comm. 2013; Figure 2).

Nahanni Aster grows around the edge of the springs and along the streams and seepage discharging from the spring (Figure 5). It is most commonly rooted in "brown mosses" (especially *Tomenthypnum nitens* and *Cratoneuron filicinum*), but also occurs in broken old tufa, and dense turf with various rushes and sedges. Owen *et al.* (2006) also reported it rooting in *Sphagnum* and that some plants grow "hydroponically" with exposed roots in open warm water). Microsites with Nahanni Asters are typically unshaded by trees or shrubs. Common associates of Nahanni Aster (in approximate decreasing order of frequency) include Marsh Grass-of-Parnassus (*Parnassia palustris*), Mountain Death Camas (*Zygadenus elegans*), Sticky False Asphodel (*Triantha glutinosa*), Shrubby Cinquefoil (*Dasiphora fruticosa*), Common Butterwort (*Pinguicula vulgaris*), Kalm's Lobelia (*Lobelia kalmia*), Starry False Solomon's Seal (*Maianthemum stellatum*), and Yellow Monkey-flower (*Mimulus guttatus*). Sedges (*Carex* spp.) and rushes (*Juncus* spp.) were associated with all Nahanni Aster sites, but were not identified to species. These species are also present at many springs in the Nahanni area without Nahanni Aster.

Figure 5. Old Pots Hotspring. (Photo by Allan Harris).

The water temperature at Old Pots spring is much cooler than other springs where Nahanni Aster occurs, and it is thought that it was a hot spring at one time but is now cool. The 'old pots' that led to the name are large tufa / travertine gours (bathtub-like pools), but all are highly weathered and overgrown, and there is little or no apparent ongoing deposition of calcium carbonate over much of the site. Currently, a cold stream begins above the pots, flows into a beaver pond, and then through the tufa deposits.

Water temperatures ranged from 10 to 29°C (see Table 1; Appendices 1 and 2 for attributes), but are expected to be relatively stable year-round. All six hot springs with Nahanni Aster occur between 642 to 795 m above sea level. Sibbeston Hotspring is different from the other sites in that the spring consists of a seepy hillside with cobbles encrusted with calcium carbonate but lacks tufa terraces. Unlike the other hot springs with carbonate precipitates, Hotspring 86-030 has extensive red mounds of iron oxides. Ten other hot springs with tufa were surveyed in 2012 but none supported Nahanni Aster (Harris and Foster 2012).

Water chemistry and temperature data collected by Caron *et al.* (2007) suggest that springs with Nahanni Aster are basic or only slightly acidic, with low concentrations of trace elements, and warm temperatures (except for Old Pots as noted above) (Appendix 2). About ten of the unsurveyed springs have these habitat attributes (Caron *et al.* 2007; Appendix 2).

Habitat Trends

Habitat trends at the hot spring sites are not well known, but probably little changed in historical times. The Rabbitkettle Hotspring and tufa mounds are the best known of the sites where Nahanni Aster is known to occur. The area has been of geological interest since at least the 1930s (Lewis 1997), and was the subject of an MSc. thesis (Gulley 1993). The site also features prominently in some Dene legends of the Nahanni area (Parks Canada 2009), but there is no known reference to the Nahanni Aster in these stories. The north tufa mound has experienced some effects of human trampling in the past, but this does not include the area where Nahanni Aster occurs, and has had no discernible impact on habitat.

Wildmint Hotspring has some history of human use, but it is not well documented. The site is marked on some topographic maps with a mine symbol (pickaxe graphic). It is also the site of a small, semi-subterranean cabin built in 1971 (Scotter *et al.* 1971) in a clearing beside the main pool, but no details are known about the builder, period of occupancy or activities at the site. The cabin remains are quite hidden, and there is little other evidence of human impact. Intermittent photo-monitoring of the site has been conducted by Park staff since the 1980s, and no large-scale changes are apparent. Access to the site is restricted through park zoning (Parks Canada 2010), so direct human impacts are not likely to occur.

As described above, Old Pots is much cooler than other sites of Nahanni Aster occurrence, and calcium carbonate deposition no longer occurs. Currently, a cold stream begins above the pots, flows into a beaver pond, and then through the tufa deposits. Nahanni Aster has apparently been able to persist since changes in spring water discharge (or has colonized this spring after the change). In either case, the persistence of Nahanni Aster suggests that the species is tolerant of cooler spring temperatures and non-tufa accumulating environments where tufa has been previously deposited. There is no evidence of human impacts at this site.

The remaining three sites are recently discovered, and there is no known trend in habitat condition at these sites.

BIOLOGY

Very little is known of the biology of Nahanni Aster. The only published sources of information are the original species description by Scotter and Cody (1974), and brief accounts based on John Semple's field and laboratory work in the Flora of North America (Brouillet *et al.* 2006) and Owen *et al.* (2006). Much of what is presented below is based on limited field observations in 2012 (Harris and Foster 2012) or summarized from other species of *Symphyotrichum*.

Life Cycle and Reproduction

Nahanni Aster is a perennial species forming clumps of flowering stems with multiple shoots. It reproduces both by seed and asexually using short rhizomes. Flowering occurs in August to September. Seed production has not been measured, but flowering stems have 1 to 15 or more flower heads, each with 20 to 60 disk florets (Brouillet *et al.* 2006), suggesting that each individual can produce several hundred seeds annually. Apomixis (asexual production of seed) is apparently uncommon in *Symphyotrichum* (Noyes 2007). Noyes (2007; citing Semple pers. comm.) concludes that apomixis does not occur regularly given that odd-ploidal chromosome numbers are rare in the genus.

Details on seed maturation, germination timing, and seed dormancy for Nahanni Aster have not been documented. Asters are typically pollinated by insects (Semple *et al.* 1996). Insects observed visiting Nahanni Aster flowers during 2012 fieldwork include Northwestern Fritillary (*Speyeria hesperis*), a sulphur (*Colias* sp.), Dorcas Copper (*Lycaena dorcas*), Cryptic Bumble Bee (*Bombus cryptarum*), and a diurnal moth (Lepidoptera). Many asters are self-incompatible and require a genetically different individual to achieve pollination (Cullina 2000). Seeds of Lance-leaved Aster, *Symphyotrichum lanceolatum* mature in 3-4 weeks after pollination and are dispersed by wind (Chmielewski and Semple 2001). Little germination occurs in the fall in Lance-leaved Aster and most seedlings appear in the following spring. Seeds of some members of the genus *Symphyotrichum* can germinate without cold stratification, but germination rate increases after refrigeration in a moist atmosphere (e.g. Chmielewski and Semple 2001, 2003; Kemp and Lacroix 2006). *Symphyotrichum* seeds are often short-lived and persist only a few years in the seed bank (e.g. Chmielewski and Semple 2003; Kemp and Lacroix 2006). Most perennial asters survive the dormant season as rosette shoots. These are typically produced from late July until the first killing frost (Chmielewski and Semple 2001, 2003). Individuals of Lance-leaved Aster can produce seed in their first year after germination (Chmielewski and Semple 2001). Longevity of Nahanni Aster clones is unknown, but other species of *Symphyotrichum* have been recorded to live for over 10 years (Brouillet pers. comm.; Bennett pers. comm.).

Physiology and Adaptability

Nahanni Aster occurs exclusively at a limited number of hot springs in a small geographic area, suggesting that it tolerates a narrow range of habitat conditions. The areas immediately surrounding hot springs presumably offer year-round moderate temperatures and a relatively steady water and nutrient supply. Nutrient availability may also be greater than other surface water habitats although data are lacking. Nahanni Aster was raised from rootstocks in the laboratory by Semple *et al.* (Owen *et al.* 2006).

Dispersal and Migration

Dispersal presumably occurs by wind-borne seeds, as is the case with other aster species. Dispersal between hot springs is probably limited by the scarcity of suitable habitat. Ten additional hot springs with tufa (but lacking Nahanni Aster populations) are known to occur to the north, west, and east of known populations (Figure 2) but the total habitat is small (probably less than 200 ha distributed over an area of over 25,000 km^2). Dispersal between the four relatively closely clustered sites (Old Pots, Wildmint, Thirteen Steps, and 86-030; within approximately a 10 km radius) is more likely than dispersal between Rabbitkettle and Sibbeston, which are more isolated.

Despite the distribution of subpopulations in small and dispersed habitat patches, Nahanni Aster is not considered to have a "severely fragmented" distribution because seeds are assumed to be produced in large numbers and widely dispersed by the wind. For meeting this criterion, more than half of the individuals must be in small and isolated patches that are not large enough to maintain viable populations (IUCN 2010).

Interspecific Interactions

Interspecific interactions between Nahanni Aster and other species are unknown. No herbivory was observed on any plants in 2012. See notes on pollinators under **Life Cycle and Reproduction**.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

A previous survey by Dr. John Semple (University of Waterloo) and Douglas Tate was conducted over four days (22-25 August 2003) and included the three previously known sites (Old Pots, Rabbitkettle, Wildmint), one new site where Nahanni Aster was discovered (Thirteen Steps), and five other potential sites (nine in total) (Semple pers. comm. 2006, 2011). Visits to sites with asters were up to several hours, while sites without were typically shorter. The surveys consisted of two observers walking most of the open area surrounding the hot springs, estimating number of shoots, and collecting material at some sites. The survey duration ranged from 0.5 hours to 3.5 hours per site depending on the size of the area occupied.

Parks Canada has completed informal monitoring of Nahanni Aster habitat at hot springs between 2000 and 2012 (Doug Tate, unpubl. data). The habitat was photographed and the distribution of Nahanni Asters noted. Stem counts were not conducted. Standard photographs of the Wildmint site have been compiled as a larger-scale physical change monitoring program.

The 2012 survey was conducted by helicopter on August 14 to 16, 2012 (Appendix 1) (Harris and Foster 2012). Survey destinations were based upon (i) a digital database and map of 66 spring localities compiled by Parks Canada based on Wright *et al.* (2007) and (ii) previous survey data described above, and (iii) unpublished documents and personal communications from Dr. John Semple and Douglas Tate. Five sites visited in previous surveys or informally surveyed by park staff (Lened, Moore's, Kraus, Hole in the Wall, Glacier Lake) but found to lack suitable tufa habitat were not resurveyed in 2012. The remaining springs had not been surveyed for this species.

The area encompassed about 300 km X 100 km. Most of the sites were within the Nahanni National Park Reserve, but extended outside the park to the east and west, as well as within the recently announced Naats'ihch'oh National Park Reserve (Parks Canada 2010, 2013). The timing was planned to coincide with the peak flowering period of Nahanni Aster as documented in previous studies. Personnel included Robert Foster and Allan Harris of Northern Bioscience and Douglas Tate of Parks Canada for a total of nine person-days of survey effort (Harris and Foster 2012). Six additional springs were searched for Nahanni Aster by Bruce Bennett and others in August 2012 in conjunction with vegetation classification fieldwork (Bennett pers. comm. 2012; Appendix 1).

The survey was designed to optimize the helicopter budget, with a priority on documenting the extent of occurrence and number of occurrences rather than collecting detailed habitat and demographic data. A relatively brief stop (typically 0.5 to 1 hour) was made at each site. The number of flowering stems and area of habitat occupied were estimated, and notes on habitat were compiled. For the sake of population size estimates, each flowering stem was treated as a "mature individual" because each flower-bearing stem is inferred to be capable of reproduction (COSEWIC 2012).

Abundance

If each flowering stem is considered to be a mature individual, over 5600 individuals were estimated in 2012 (Table 1). The number of individual plants is unknown because the clonal growth form of Nahanni Aster makes counting individual plants very difficult. Comprehensive population trend data are unavailable, but more flowering stems were recorded in 2012 than in previous surveys at the four sites where comparable data are available (Table 1).

An alternative definition of individual is a multi-stemmed, flowering clump. This number can be roughly calculated using the estimated 2-10 stems/clump observed in the field in 2012 and the minimum number of flowering stems of 5638. This gives a range of 564-2819 individuals with a median value of 1691. Regardless of which estimate is accepted, more than 1000 individuals probably occur in Canada.

Of the 70 springs in the Nahanni area, 61 were surveyed between 2003 and 2012 (Appendix 1). Nine springs in the Nahanni area and a few additional springs elsewhere in NWT, Yukon, and northern BC have not been surveyed for Nahanni Aster.

Fluctuations and Trends

Precise Nahanni Aster population fluctuations and trends are unknown due to the lack of consistent and comprehensive surveys. Comparison of the 2003 survey notes (Semple pers. comm.) and 2012 data show no apparent change in the distribution of plants or area occupied. Parks Canada staff observations from 2000 to 2012 also suggest that the extent of asters, density of plants, and other aspects of the habitat appear to be little changed (Tate, pers. obs.).

Rescue Effect

No rescue is possible because the entire global population is in Canada.

THREATS AND LIMITING FACTORS

Most of Nahanni Aster habitat is isolated from industrial development and roads, but its extremely limited range (six occurrences covering less than 10 ha in total) make it vulnerable to random environmental events.

Wildmint Hotspring has some history of human use, but it is not well documented. The site is marked on some topographic maps with a mine symbol (pickaxe graphic). It is also the site of a small, semi-subterranean cabin built in 1971 (Scotter *et al.* 1971) in a clearing beside the main pool, but no details are known about the builder, period of occupancy or activities at the site. The cabin remains are quite hidden, and there is little other evidence of human impact.

Public access to the Rabbitkettle Hotsprings area, prior to park establishment and during the early years of park management, has caused some localized damage to the tufa mounds at the site (Catto 1987; Gulley 1993). The area was given protection as a Special Preservation Area (Zone I) under the first park management plan, and this status remains in place today (Environment Canada Parks 1987; Parks Canada 2010), limiting public access to staff-guided interpretive hikes. Even with the previous use, there has been no perceptible impact to the area in which Nahanni Aster grows at the site (Tate pers. obs.).

Similar zoning protection (no unaccompanied public access) is afforded to both Wildmint and Old Pots springs under the management plan. Due to the very low frequency of visitor use on the Flat River, the risk from human traffic and trampling is not considered a significant threat at these sites. Access to Thirteen Steps and 86-030 springs is similarly constrained, and these sites are even less well known to the public. Sibbeston Hotspring is well away from any common visitor travel routes. In addition, aircraft access outside designated landing sites is strictly regulated. Alteration to hot spring travertine habitats from trampling by ungulates (Moose, *Alces americanus*, and Woodland Caribou, *Rangifer tarandus caribou*) is more likely than physical impacts from humans; evidence of this is apparent at Wildmint Hotsprings, but it does not appear to be negatively impacting the Nahanni Aster population at the site (Tate pers. obs.).

Invasive plants are a potential future threat, but are confined primarily to disturbed sites such as the Kraus homestead (Scotter and Cody 1974; Cody, *et al.* 1979; Bennett 2012). The park reserve surrounds an advanced exploration site and mine under development at Prairie Creek with a road proposed to access the mine (MVRB 2013). Another mine access road passes through the northwest portion of the park expansion area (Parks Canada 2010). An increase in access roads related to resource development is providing a vector for additional species; evidence of this was seen in 2012 (Bennett pers. comm.). None of these road proposals are in close proximity to aster sites, however, with the nearest being Sibbeston Hotspring ~ 20 km west of the Prairie Creek access road.

Climate change is a more likely driver of change to hot springs, and Nahanni Aster habitat. The climate in Nahanni National Park Reserve and vicinity in recent decades is significantly warmer than the 1950 to 1979 period, based on Environment Canada weather station records from Fort Simpson as a proxy (Parks Canada 2009). This has resulted in a longer and warmer growing season and increased August rains. Snowfall has increased, but the warmer winters have resulted in decreased snowpack and earlier spring (Parks Canada 2009). The potential threats to Nahanni Aster are speculative; changes in precipitation or runoff could alter groundwater discharge, although the observed pattern of increased precipitation could also increase groundwater discharge and available habitat.

Seismic activity (e.g. fault movements and earthquakes) also has the potential to impact Nahanni Aster populations through alterations to groundwater discharge, which then influence habitat. A seismic fault shift could reduce or stop groundwater flows at a spring.

The Nahanni area is one of the most active seismic regions in Canada. Strain transfer from the collision of the Yakutat Terrane in coastal Alaska reaches the surface along the eastern edge of the Mackenzie and Richardson Mountains, resulting in seismic activity and very high temperatures beneath the eastern Cordillera (Mazzotti and Hyndman 2002). In 1985, two major earthquakes occurred in the Sombre Mountains near the North Nahanni River on October 5 (magnitude 6.6) and December 23 (magnitude 6.9). Although neither quake ruptured the surface, the first earthquake produced a huge rock avalanche at the surface. Earthquakes continued for several years, including a magnitude 6 event in 1988 (Cassidy *et al.* 2010). The seismic activity was not traceable to any mapped faults, but instead to a 'blind' fault that doesn't reach the surface (Wetmiller *et al.* 1988). Five seismic events were recorded in the area northeast of Virginia Falls between August 1996 and March 1997. A large landslide in the winter of 1996-97 at Clearwater Creek was probably triggered by these events (Parks Canada 2014).

Nahanni Aster populations are vulnerable to changes in spring discharge caused by seismic events. Hot spring flow elsewhere in western Canada has been altered and even stopped by earthquake activity, even when the seismic activity occurs hundreds of km away (Grasby pers. comm.). However, Nahanni Aster may be able to persist after spring discharge has been altered as has apparently been the case at Old Pots.

Increases in slumping of soil and rock have been noted by Nahanni Park staff in recent years, and are probably due in part to permafrost melt, but seismic activity may also be involved. An assessment of landslide hazards in Nahanni National Park Reserve was undertaken as part of the feasibility studies for park expansion, and concluded that the Tlogotsho Range and Ram Plateau were the most active areas (Jermyn and Menounos 2006; Jermyn et. al. 2006). Although Nahanni Aster populations may be vulnerable to being devastated by slumping, none of the identified populations are in the higher risk slide zones.

Number of Locations

Assuming that changes in geothermal discharge due to climate change or tectonic activity is the single greatest threat facing Nahanni Aster, each of the six hot springs represents a distinct "location". Each spring has a unique geographical setting and will likely respond differently to changes in precipitation and runoff.

The number of additional locations that can possibly be discovered with additional surveys may be calculated based on habitat requirements (see **Habitat Requirements**) and the number of known springs with good habitat that remain unsurveyed. The Nahanni Aster was found present at four springs with a range of water chemistry and temperature apparently appropriate for its survival, but not at another four springs with the same conditions (50% presence rate). Of the ten unsurveyed springs with similar conditions, we can extrapolate that a maximum of an additional five sites remain to be discovered.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Nahanni Aster receives no specific protection under federal or territorial laws; however, as all known sites are within Nahanni National Park Reserve, it does receive protection under the *Canada National Parks Act* (CNPA) and Regulations. Under the CNPA, picking of any plants (removal or destruction of a natural object) is prohibited; scientific collection of any kind requires a Parks Canada Research Permit.

Non-Legal Status and Ranks

NatureServe (2012) provides the following ranks:

Global Rank: G1 – Critically Imperilled (last reviewed 07 February 2010)

National Rank (Canada): N1

Northwest Territories: S1

The General Status Rank is 2 "May be at Risk" for Northwest Territories and Canada (Wild Species 2010). The status in the Northwest Territories is scheduled to be assessed in 2014 (Species at Risk Committee 2012).

Habitat Protection and Ownership

When Nahanni National Park Reserve was established, it encompassed 4765 km^2 centred on the South Nahanni and Flat river corridors (the status as a "reserve" indicates that traditional renewable resource harvesting activities by Aboriginal persons is permitted but the area is otherwise managed as a national park). In 2009, the park boundaries were expanded to include 30,000 km^2 of lands and waters in the South Nahanni and adjacent North Nahanni River watersheds (Parks Canada 2010). Four of the Nahanni Aster sites (Rabbitkettle, Old Pots, Wildmint, and Thirteen Steps hotsprings) are within the original park boundary, and the remaining two (Sibbeston and 86-030) are within the expanded boundary.

As noted above, three of the Nahanni Aster populations are within areas designated as Special Preservation Areas (Zone I) under the *Nahanni National Park Reserve of Canada Nah'a Dehe Management Plan* (2010), which restricts public access to approved scientific research or, in the case of Rabbitkettle Hotsprings, staff-guided interpretive hikes. The fourth site within the original boundary, Thirteen Steps, is in a zone known as Wilderness (Zone II), which allows non-motorized access. The remaining two springs in the expansion area have not yet been formally zoned, although this is an action identified for the next park management plan (Parks Canada 2010, p. 36).

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Authorities Contacted

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Allan Harris is a biologist with over 20 years' experience in northern Ontario. He has a B.Sc. in Wildlife Biology from the University of Guelph and an M.Sc. in Biology from Lakehead University. After spending seven years as a biologist with the Ontario Ministry of Natural Resources, he co-founded Northern Bioscience, an ecological consulting company based in Thunder Bay, Ontario. Al has authored or coauthored dozens of scientific papers, technical reports, and popular articles, including COSEWIC status reports for Gibson's Big Sand Tiger Beetle, Bogbean Buckmoth, Rapids Clubtail, Laura's Clubtail, Riverine Clubtail, Georgia Basin Bog Spider, Hoptree Borer, Northern Barrens Tiger Beetle, Bluehearts, Small-flowered Lipocarpha, and Drooping Trillium. Al also authored the Ontario provincial status report for woodland caribou, and has authored or coauthored national and provincial recovery strategies for vascular plants and birds. He is a member of the Committee on the Status of Species at Risk in Ontario (2008 – 2013).

Robert Foster is co-founder and principal of Northern Bioscience, an ecological consulting firm offering professional consulting services supporting ecosystem management, planning, and research. Dr. Foster has a B.Sc. in Biology from Lakehead University and a D. Phil in Zoology from the University of Oxford. Rob has worked as an ecologist in Ontario for over 20 years, and has authored or coauthored COSEWIC status reports on the Weidemeyer's Admiral, Bogbean Buckmoth, Hop-tree Borer, Laura's Clubtail, Rapids Clubtail, Riverine Clubtail, Northern Barrens Tiger Beetle, Big Sand Tiger Beetle, Crooked-stem Aster, Bluehearts, Georgia Basin Bog Spider, Gibson's, and Drooping Trillium, as well as recovery plans for rare plants, lichens, and odonates.

Douglas Tate has worked as a biologist with Parks Canada, Nahanni National Park Reserve for 14 years, and has previous work experience with both Parks Canada and the Ministry of Natural Resources in Ontario. He graduated with a B.Sc. in Wildlife Biology, and later an M.Sc., both from the University of Guelph. Doug's field research experience includes nesting surveys of Venezuelan birds, wetland classification & turtle home range studies in central Ontario and aerial moose surveys in the Northwest Territories. He has authored or coauthored several journal papers, technical reports, and popular articles, and was a member of the Northern Mountain Caribou Technical Advisory Team for developing the Management Plan. Although Doug has not authored any previous COSEWIC status reports, he has provided data for and / or reviewed reports for several species, including Yellow Rail, Common Nighthawk, Collared Pika and Bull Trout.

COLLECTIONS EXAMINED

None.

Appendix 1. Summary of 2012 Nahanni Aster survey sites. Refer to Figure 2 for localities.

No.	Name	Survey	Tufa?	Nahanni Aster?	Habitat Notes
1	Little Doctor	2012[1]	Y	N	Many calciphiles. Apparent tufa deposits.
2	Cimitar	2012[1]	N	N	No suitable habitat.
3	Big Vale	2012[1]	N	N	No suitable habitat.
4	Vale	2012[1]	N	N	No suitable habitat.
5	Corridor Creek	2012[1]	N	N	No suitable habitat.
6	Cowboy	2012[1]	N	N	No suitable habitat.
7	Cowgirl	2012[1]	N	N	Open area covering 30 m X 40 m. Above stream floodplain. Water temperature = 3°C
8	Sibbeston	2012[1]	Y	Y	Braided stream channel arising from hillside. Most plants within 1 m of stream. Calcium carbonate deposits but tufa not evident. Water temperature = 26°C
9	Wildmint	2012[1], 2003[3]	Y	Y	Tufa deposited in a series of steps, each about 50 m X 100 m. Total area occupied by Nahanni Aster about 6 ha, mostly in broken up tufa gravel. Old Beaver dam present. Water temperature = 26°C
10	86-030	2012[1]	Y	Y	Reddish iron deposits and tufa at base of treed hillside. Water temperature = 21°C
11	Descente	2012[1]	N	N	No open habitat found
12	Mineral Lake	2012[1]	N	N	No open habitat found
13	Softie	2012[1]	N	N	Little or no suitable habitat.
14	86-021	2012[1]	N	N	Large open seepy area in broad valley. Calciphiles present. H_2S smell. Water temperature = 10°C
15	87-106	2012[1]	N	N	No open habitat found
16	86-010	2012[1]	N	N	No open habitat found
17	Grizzly Bear	2012[1]	Y	N	Potential habitat. Tufa covers 5 m X 50 m. Another 50 m X 60 m of open mossy tussocks. Water temperature = >45°C
18	Broken Skull	2012[1]	Y	N	Marl deposits, slight H_2S smell. Water temperature = 43°C
19	Red Steel	2012[1]	N	N	Iron deposits. Crumbly red sandstone. Some calciphiles present. Water temperature = 10°C
20	Nahanni Headwater	2012[1]	N	N	Open area covering 100 m X 200 m with some patches of mossy tussocks. Water temperature = 30°C
21	Cotton	2012[1]	N	N	Little or no suitable habitat.

No.	Name	Survey	Tufa?	Nahanni Aster?	Habitat Notes
22	Red Mini	2012[1]	Y	N	Open seep covering 1500 m^2. *Sphagnum fuscum*-dominated. No calciphiles. Water temperature = 11°C
23	Champagne	2012[1]	N	N	Iron ppt present. Some mossy tussocks on side of stream. Water temperature = 6°C
24	North Cartung	2012[1]	N	N	Marl deposits. Large grass and sedge meadow. Lots of calciphiles. Water temperature = 32°C
25	86-060	2012[1]	N	N	Poor habitat. Fairly dry.
26	Cordes Verte	2012[1]	Y	N	Tufa covers about 3000 m^2 where spring discharges into spruce forest. Many mossy hummocks. Water temperature = 10°C
27	Flat Fruit	2012[1]	Y	N	Tufa covers about 1500 m^2. Another inaccessible extensive tufa deposit at base of cliff. No aster visible through binoculars. Water temperature = 19°C
28	Brimstone	2012[1]	Y	N	Tufa covers about 120 m^2. Water temperature = 6°C
29	Clark Lake	2012[1]	N	N	Small seep area on lakeshore. No suitable habitat.
30	Cascade	2012[1]	N	N	No suitable habitat. Beside Caribou River.
31	Selena	2012[1]	N	N	No suitable habitat.
32	Jackson	2012[1]	N	N	No suitable habitat.
33	Darkness	2012[1]	N	N	No spring observed.
34	Overflow	2012[1]	N	N	Small seepage area on bare ridge. Very dry.
35	Meltwater	2012[1]	N	N	No spring observed.
36	Interpluton	2012[1]	N	N	Marshy area on side of lake
37	Tiny	2012[1]	N	N	No suitable habitat.
38	Unnamed	2012[1]	Y	N	Tufa covers 40 m X 30 m in a series of steps between lakes. Suitable habitat present as mossy tussocks. Water temperature = 8°C
39	Rabbitkettle	2012[1], 2003[3]	Y	Y	Extensive tufa deposits. Nahanni Aster present on the smaller southern deposits. Mostly rooted in mosses at edge of open tufa.
40	Halfstep	2012[1]	N	N	No suitable habitat.
41	Cartman	2012[1]	N	N	Marshy spring on slope. No suitable habitat
42	Old Pots	2012[1], 2003[3]	Y	Y	Terraced tufa covering about 1 ha. Sedge-dominated vegetation with mosses.
43	Thirteen Steps	2012[1], 2003[3]	Y	Y	Nahanni Aster extending over about 1 ha. Many rooted in broken tufa with moss cushions and edges of tufa pools. Water temperature = 20°C

No.	Name	Survey	Tufa?	Nahanni Aster?	Habitat Notes
44	Boulder	2012[1]	N	N	Spring emerges from bouldery mountainside. Some mossy tussocks, but poor habitat.
45	Crack	2012[1]	N	N	No suitable habitat.
46	Mossy	2012[1]	N	N	No suitable habitat.
47	Sombre	2012[1]	N	N	Poor habitat.
48	Quickie	2012[1]	N	N	On stream floodplain. Poor habitat. Some iron ppt.
49	Cathedral	2012[1]	N	N	Some patches of "brown mosses". Calciphiles present. More or less on river floodplain. Water temperature = 5°C
50	Wrigley*	2012[2]	N	N	Some mossy tussocks but no tufa. On river floodplain.
51	Galena Creek*	2012[2]	N	N	Calciphiles present.
52	Bluebell*	2012[2]	Y	N	Calciphiles present.
53	Kraus*	2012[2] 2003[3]	N	N	Calciphiles present. No tufa.
54	Brigade*	2012[2]	N	N	Calciphiles present.
55	Caribou*	2012[2]	N	N	Calciphiles present.
56	Chance*	2012[2]	N	N	Calciphiles present.
57	Moore's	2003[3]	N	N	No suitable habitat.
58	Meilleur	2003[3]	N	N	No suitable habitat.
59	Lened	2003[3]	N	N	No suitable habitat.
60	Hole in the Wall	c. 2006[4]	N	N	No suitable habitat.
61	Glacier Lake	c. 2006[4]	N	N	No suitable habitat.
62	Bougere	None	?	?	
63	Grasby	None	?	?	
64	Karst	None	?	?	
65	Muddy	None	?	?	
66	Smurf	None	?	?	
67	W. Cantung	None	?	?	
68	Stinky	None	?	?	
69	Persistent	None	?	?	
70	Stinky Drift	None	?	?	
	Tulita[5]	None	?	?	Not mapped in Figure 2

No.	Name	Survey	Tufa?	Nahanni Aster?	Habitat Notes
	Sculpin[5]	None	?	?	Not mapped in Figure 2
	Deca[5]	None	?	?	Not mapped in Figure 2
	Ekwi[5]	None	?	?	Not mapped in Figure 2
	Tabletop[5]	None	?	?	Not mapped in Figure 2
	Redstone Junction#1[5]	None	?	?	Not mapped in Figure 2
	South Redstone[5]	None	?	?	Not mapped in Figure 2

[1] surveyed by Harris and Foster (2012); [2] surveyed by Bruce Bennett *et al.*; [3] surveyed by Semple and Tate; [4] surveyed by Parks Canada staff; [5] additional springs from Caron *et al.* 2007

Appendix 2. Water chemistry and temperature data of 70 springs in the Nahanni area from Caron *et al.* (2007). Temperature (based on a single surface water temperature measured during the summer), pH, and total trace element classes were derived by Caron *et al.* (2007). Hot springs are >40°C, warm springs are 39° C to 12° C, and cold springs are < 12° C. Caron *et al.* (2007) did not sample Old Pots or Thirteen Steps springs.

Spring	Nahanni Aster Present?	pH	T (°C)	pH Class	Temp Class	Total Trace Elements > 0.9%?
Sombre	No	8.67	0.30	Basic	Cold	Yes
Red Steel	No	6.65	0.80	Acidic	Cold	No
Boulder	No	8.79	0.80	Basic	Cold	No
Descente	No	7.49	0.80	Basic	Cold	No
Darkness	No	6.40	1.00	Acidic	Cold	No
Cowboy	No	7.87	1.25	Basic	Cold	No
Mossy	No	7.61	1.40	Basic	Cold	No
Tiny	No	7.64	1.40	Basic	Cold	No
Overflow	No	4.85	1.70	Acidic	Cold	Yes
Cartman	No	6.34	1.70	Acidic	Cold	No
Jackson	No	6.87	1.80	Acidic	Cold	No
Cowgirl	No	7.37	2.00	Basic	Cold	No
Cathedral	No	7.55	2.00	Basic	Cold	Yes
Chance	No	7.66	2.00	Basic	Cold	No
Muddy	Unknown	6.84	2.25	Acidic	Cold	No
Galena	No	8.01	2.30	Basic	Cold	No
Wrigley	No	6.15	2.50	Acidic	Cold	No
Bougere	Unknown	4.31	2.70	Acidic	Cold	Yes
Smurf	Unknown	7.39	2.70	Basic	Cold	No
Grasby	Unknown	7.27	3.20	Basic	Cold	No
Brigade	No	7.55	3.30	Basic	Cold	No
Clark Lake	No	7.49	3.30	Basic	Cold	No
Glacier Lake	No	7.11	3.50	Basic	Cold	Yes
Meltwater	No	7.44	3.70	Basic	Cold	No
Karst	Unknown	7.93	3.70	Basic	Cold	No
Corridor Creek	No	8.82	3.80	Basic	Cold	No
Caribou	No	7.75	3.80	Basic	Cold	No
Crack	No	7.83	4.00	Basic	Cold	No
Cascade	No	7.37	4.00	Basic	Cold	No
Interpluton	No	4.41	4.10	Acidic	Cold	Yes

Spring	Nahanni Aster Present?	pH	T (°C)	pH Class	Temp Class	Total Trace Elements > 0.9%?
Red Mini	No	3.94	4.15	Acidic	Cold	Yes
Half Spring	No	7.60	4.50	Basic	Cold	No
Veil	No	8.17	4.80	Basic	Cold	No
Big Veil	No	8.37	4.80	Basic	Cold	No
Champagne	No	6.43	5.85	Acidic	Cold	No
Brimstone	No	5.89	6.20	Acidic	Cold	No
Softie	No	5.53	6.30	Acidic	Cold	Yes
Quickie	No	7.98	7.00	Basic	Cold	No
Selena	No	7.24	7.60	Basic	Cold	No
Blue Bells	No	7.41	7.60	Basic	Cold	No
Cordes Vertes	No	7.22	8.20	Basic	Cold	No
Flat Fruit	No	6.29	9.30	Acidic	Cold	No
Cimitar	No	6.79	11.90	Acidic	Cold	No
Cotton	No	3.77	12.45	Acidic	Warm	Yes
Redstone Junction#1	Unknown	7.36	15.40	Basic	Warm	No
Stinky Drift	Unknown	8.76	16.60	Basic	Warm	No
Sibbeston	Yes	7.65	16.90	Basic	Warm	No
Sculpin	Unknown	7.03	17.05	Basic	Warm	No
Mineral Lake (86-030)	Yes	6.68	18.30	Acidic	Warm	No
Persistent	Unknown	6.07	20.50	Acidic	Warm	No
N. Cantung /Zenchuck Cr.	No	7.61	20.90	Basic	Warm	No
Rabbitkettle	Yes	5.74	21.10	Acidic	Warm	No
Deca	Unknown	7.10	21.60	Basic	Warm	No
Stinky	Unknown	6.74	24.10	Acidic	Warm	No
Tulita	Unknown	7.05	24.65	Basic	Warm	No
Broken Skull Up. Pool	No	7.18	27.90	Basic	Warm	No
Wildmint	Yes	6.63	30.00	Acidic	Warm	No
Kraus/ Clausen	No	6.54	36.70	Acidic	Warm	No
Meilleur River	No	6.63	36.90	Acidic	Warm	No
Tabletop	Unknown	7.67	38.50	Basic	Warm	No
Hole in the Wall	No	8.43	40.20	Basic	Hot	No
Ekwi	Unknown	6.69	40.80	Acidic	Hot	No
West Cantung	Unknown	8.39	41.30	Basic	Hot	No
Grizzle Bear	No	6.78	42.60	Acidic	Hot	No
Broken Skull Lw. Pool	No	6.46	46.30	Acidic	Hot	No
Broken Skull	No	6.38	46.40	Acidic	Hot	No

Spring	Nahanni Aster Present?	pH	T (°C)	pH Class	Temp Class	Total Trace Elements > 0.9%?
Moore's	No	6.75	48.20	Acidic	Hot	No
South Redstone	No	7.51	51.20	Basic	Hot	No
Nahanni N./Lened Cr.	No	8.66	56.10	Basic	Hot	No
Nahanni Headwaters	No	8.30	63.60	Basic	Hot	Yes

Appendix 3. Threats assessment worksheet.

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	*Symphyotrichum nahanniense* (Nahanni Aster)
Element ID	**Elcode**
Date (Ctrl + ";" for today's date):	02/10/2013
Assessor(s):	Suzanne Carriere
References:	NWT SARC 2013 Species status report on Nahanni Aster in the NWT. Review Draft October 2013

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	0	0
D	Low	0	0
Calculated Overall Threat Impact:			

Assigned Overall Threat Impact:	**U = Unknown**
Impact Adjustment Reasons:	Negligible or impossible to estimate
Overall Threat Comments	Recreational activities are at present negligible as a threat to the plant, this may change if or when more people access hot springs in the Nahanni area. Other threats are only speculative: changes in habitat, due to change in water discharge or water temperature because of climate change or because of seismic activity (e.g., earthquakes).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors						
4.1	Roads & railroads						
4.2	Utility & service lines						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use						
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs/3 gen)	
6.1	Recreational activities		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs/3 gen)	Only Rabbitkettle Hotsprings area has public access, the other sites have very low human activities and are difficult to access. Even in Rabbitkettle, there is no observable damage to the plant. SARC 2013 Pages 25-26
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications						
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes						
8.1	Invasive non-native/alien species		Not Calculated (outside assessment timeframe)			Insignificant/Negligible (Past or no direct effect)	None of these road proposals are in close proximity to aster sites, however, with the nearest being Sibbeston Hotspring, which is around 20 km west of the Prairie Creek access road. SARC 2013 page 26
8.2	Problematic native species						
8.3	Introduced genetic material						
9	Pollution						
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10.2	Earthquakes/tsunamis		Not Calculated (outside assessment timeframe)	Unknown	Slight (1-10%)	Low (Possibly in the long term, >10 yrs/3 gen)	fault movements and earthquakes) also has the potential to impact Nahanni Aster populations through alterations to groundwater discharge, which may then influence habitat. However, Nahanni Aster may be able to persist after spring discharge has been altered as has apparently been the case at Old Pots. (SARC 2013, page 26)
10.3	Avalanches/landslides						
11	Climate change & severe weather						
11.1	Habitat shifting & alteration		Not calculated (unknown timing)			Unknown	The potential threats to Nahanni Aster are speculative; changes in precipitation or runoff could alter groundwater discharge, although the observed pattern of increased precipitation could also increase groundwater discharge and available habitat. (SARC 2013 page 26)
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding						

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).